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(54) **LOUDSPEAKER COIL SUSPENSION SYSTEM**

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(21) Appl. No.: **09/921,191**

(22) Filed: **Jul. 31, 2001**

(65) **Prior Publication Data**

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Related U.S. Application Data

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(51) **Int. Cl.**[7] **H04R 25/00**

(52) **U.S. Cl.** **381/398**; 381/403; 381/407; 381/430; 181/171

(58) **Field of Search** .... 381/423, 424, 381/430, 398, 403, 407, FOR 162, 343, 340; 181/171, 172

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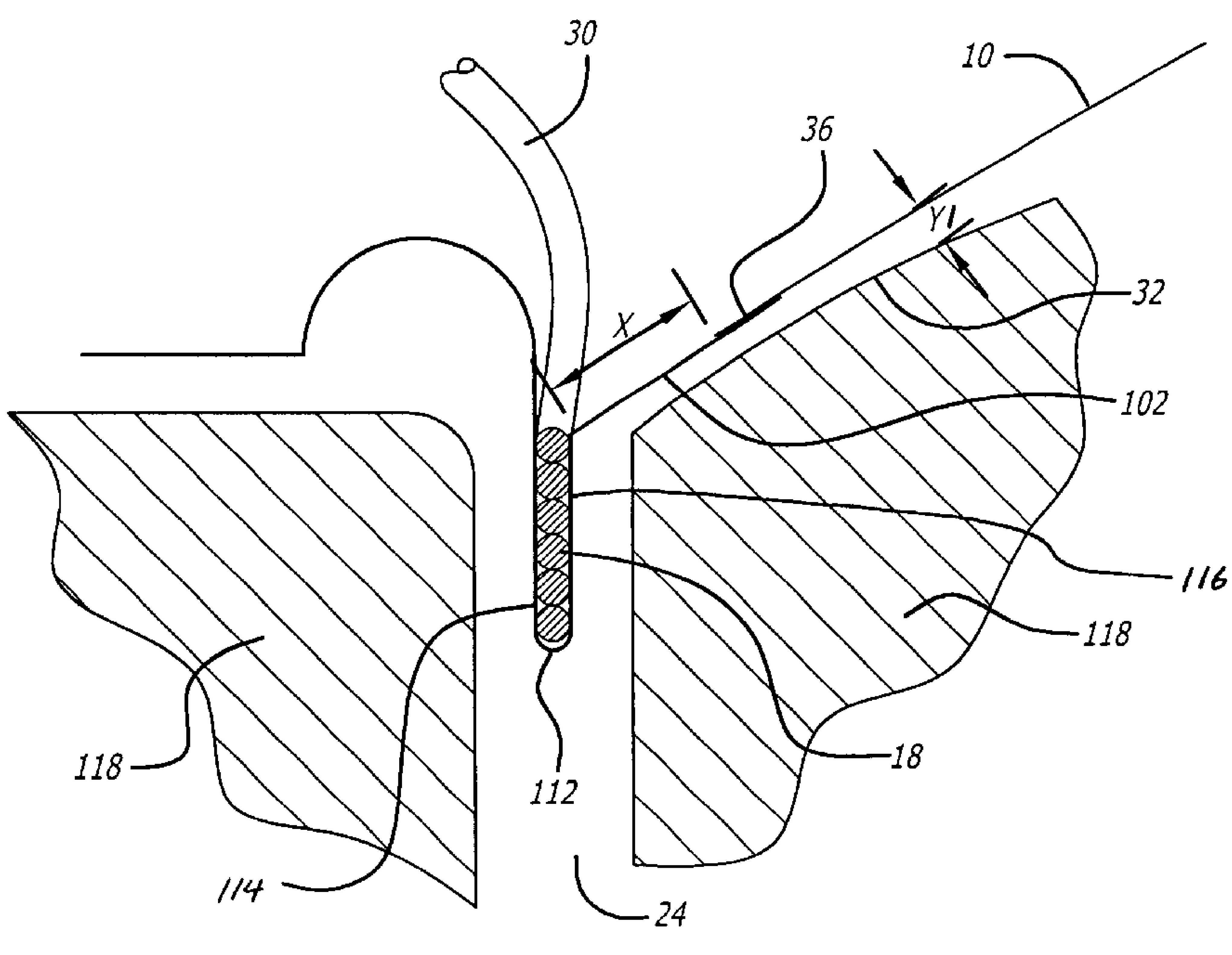
(57) **ABSTRACT**

The invention provides a continuous layer of polymer that is shaped to act as the suspension, the former, and an attachment to the diaphragm. The coil may be located within the pocket providing insulation to the coil thus preventing electrical short circuiting of the voice coil as the voice coil expands or contracts based on its operating temperature. The invention also provides an inner flange area of a suspension that may act as a spring generating additional acoustic energy from the compression driver. The inner flange area may also be tuned to vibrate at a predetermined high frequency. Thus, in certain applications, where more acoustic energy is desired at high frequency, the inner flange area may be tuned to provide that extra acoustic energy. To further increase the high frequency energy generated by the compression driver, the diaphragm may be coupled to the bottom side of the inner flange area. Such an arrangement places the diaphragm closer to the phasing plug to minimize the space or cavity between the two. With a smaller cavity, the resonance in the cavity increases, so that the compression driver generates more energy at high frequency.

19 Claims, 5 Drawing Sheets



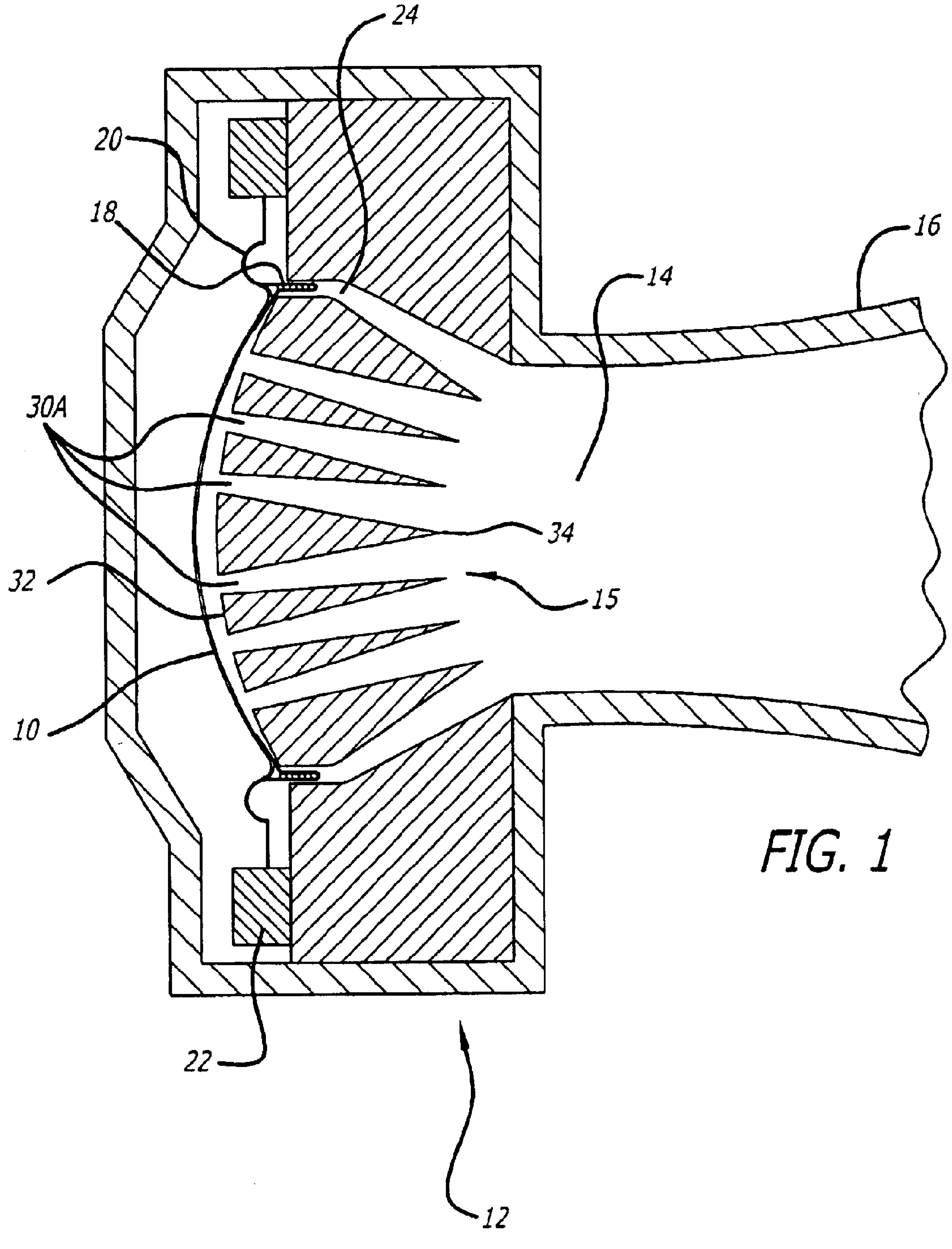


FIG. 1

FIG. 2

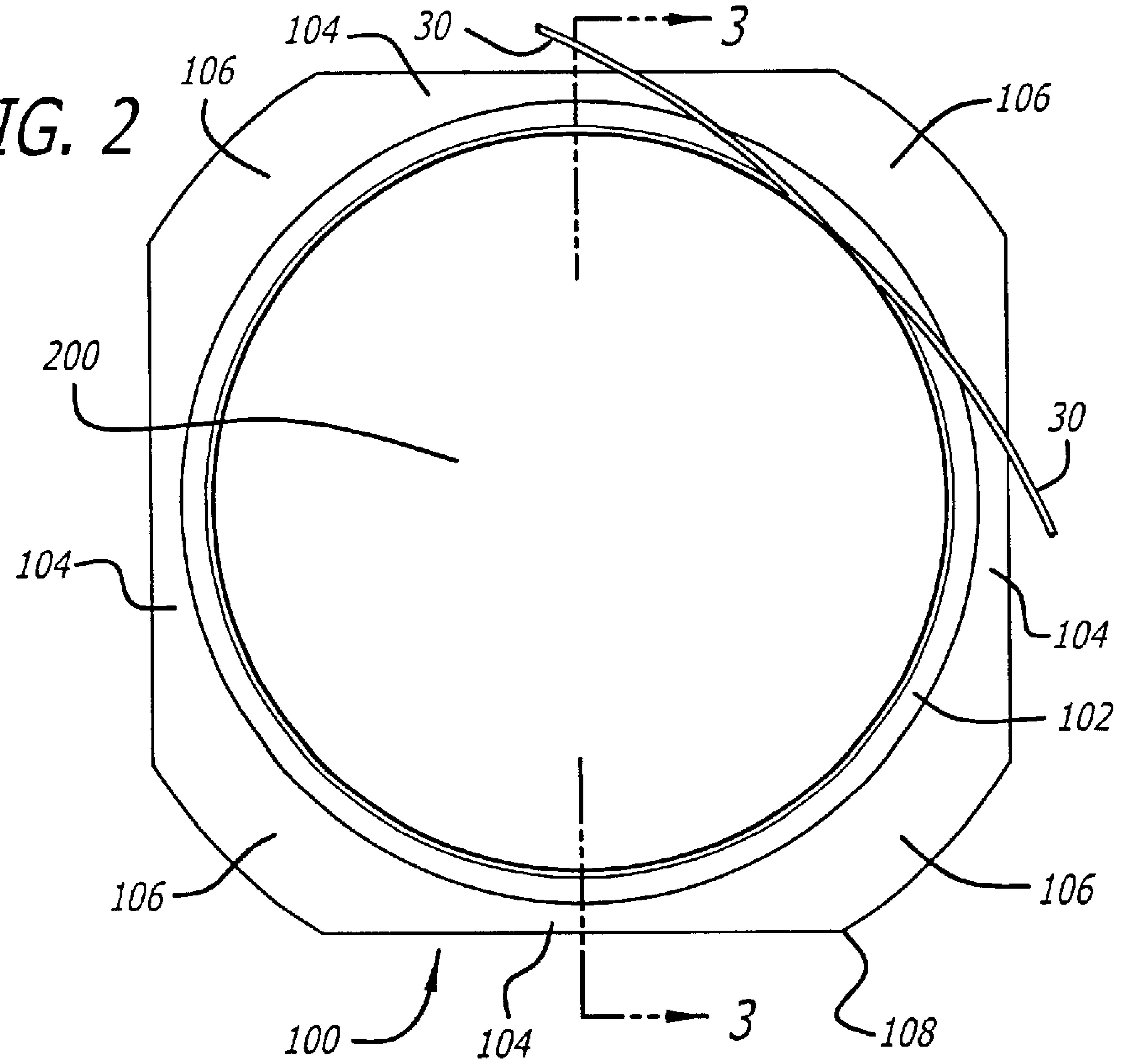
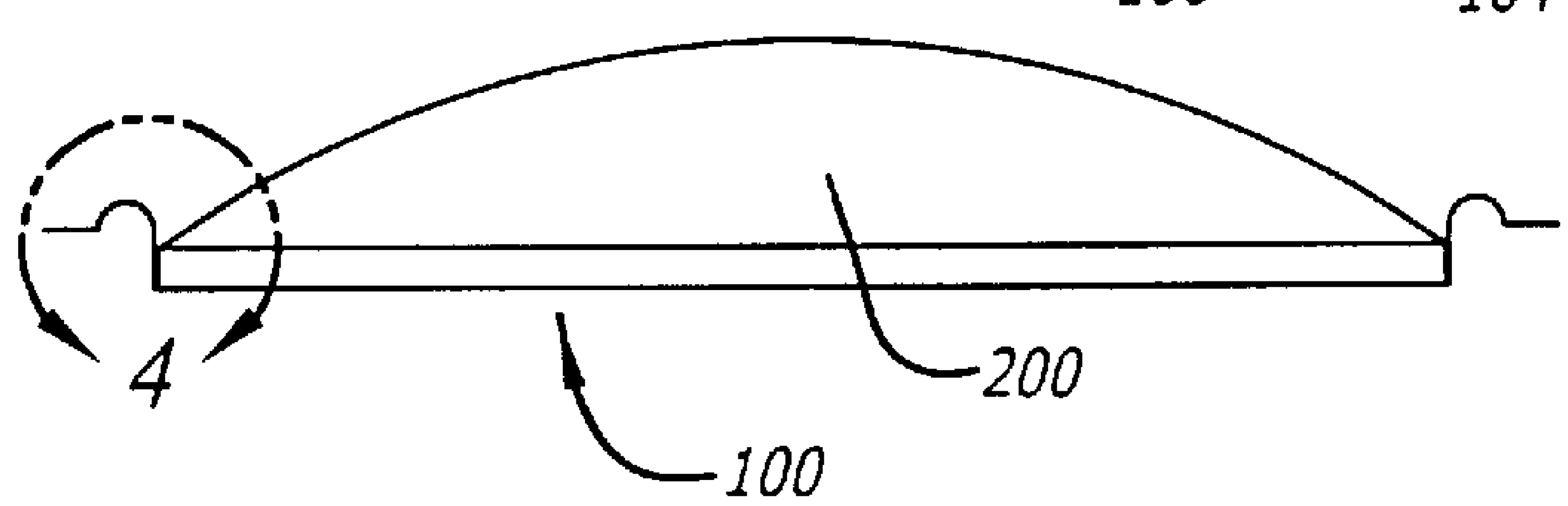


FIG. 3



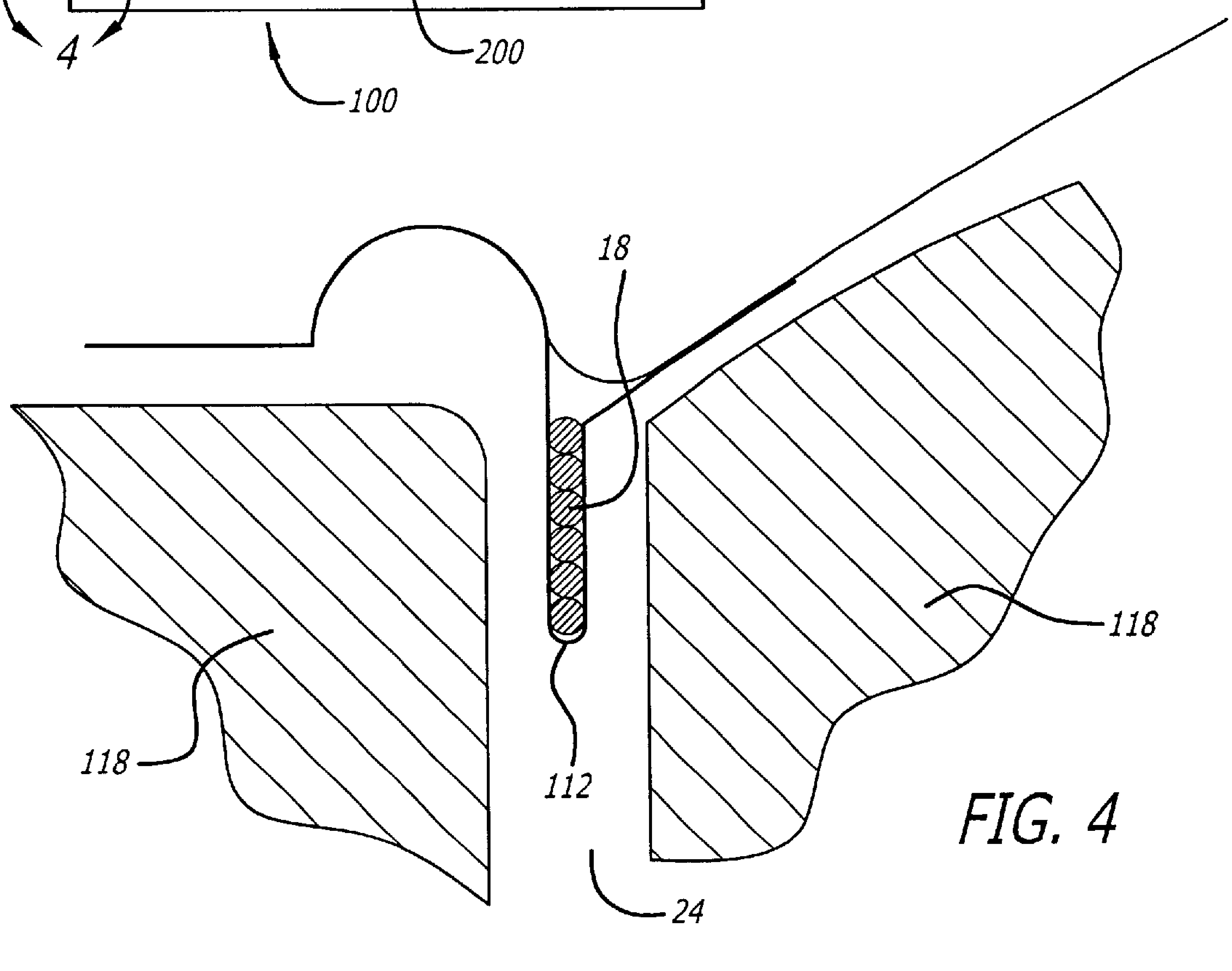


FIG. 4

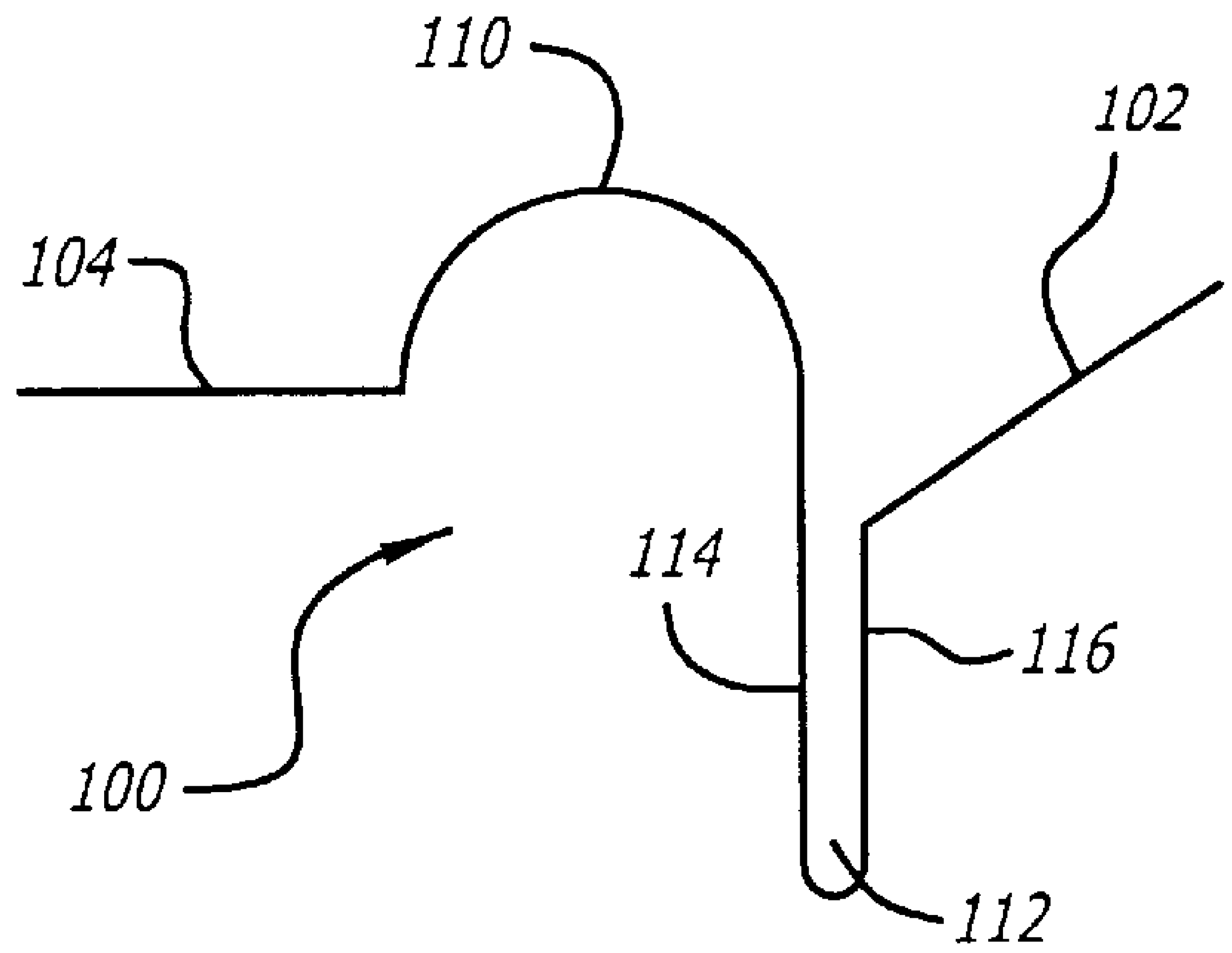


FIG. 5

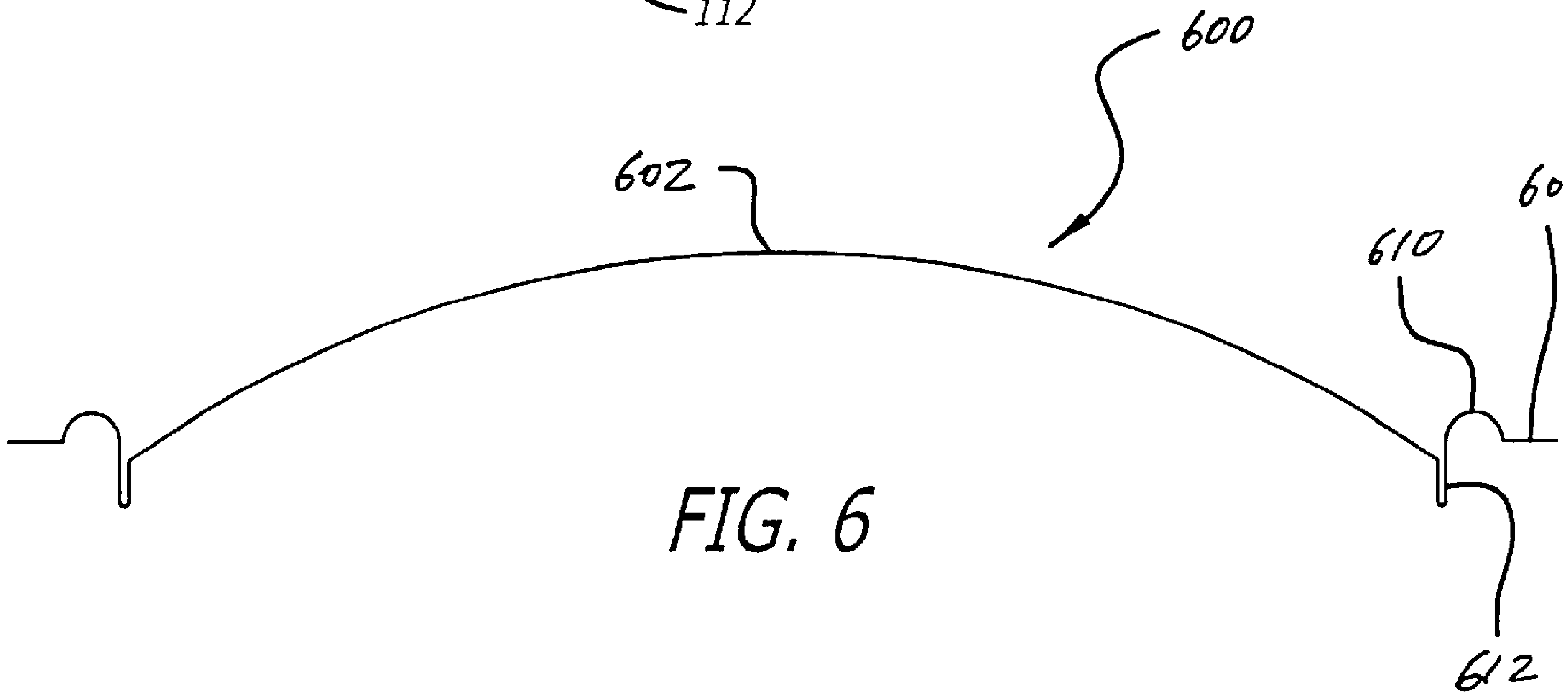


FIG. 6

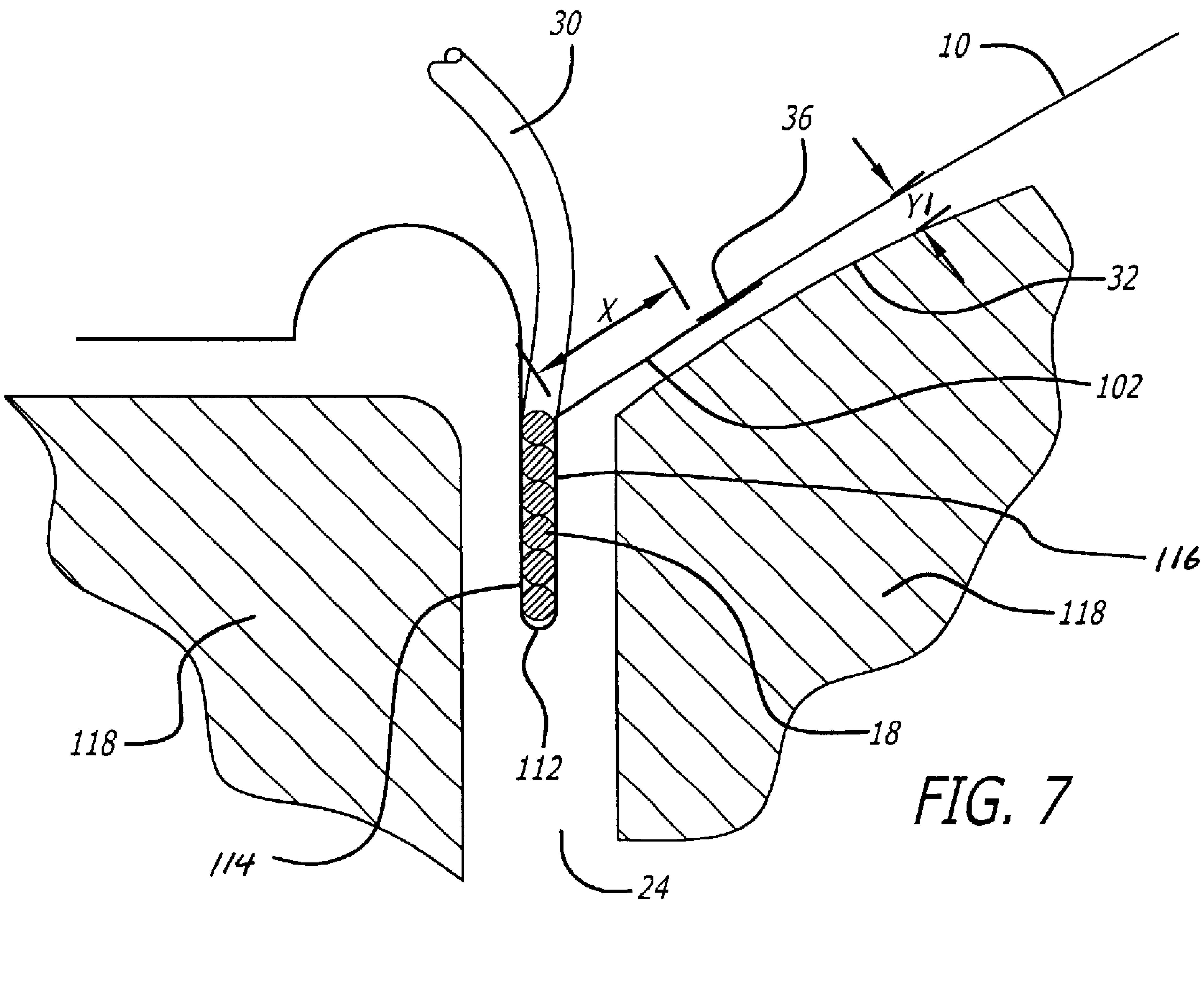


FIG. 7

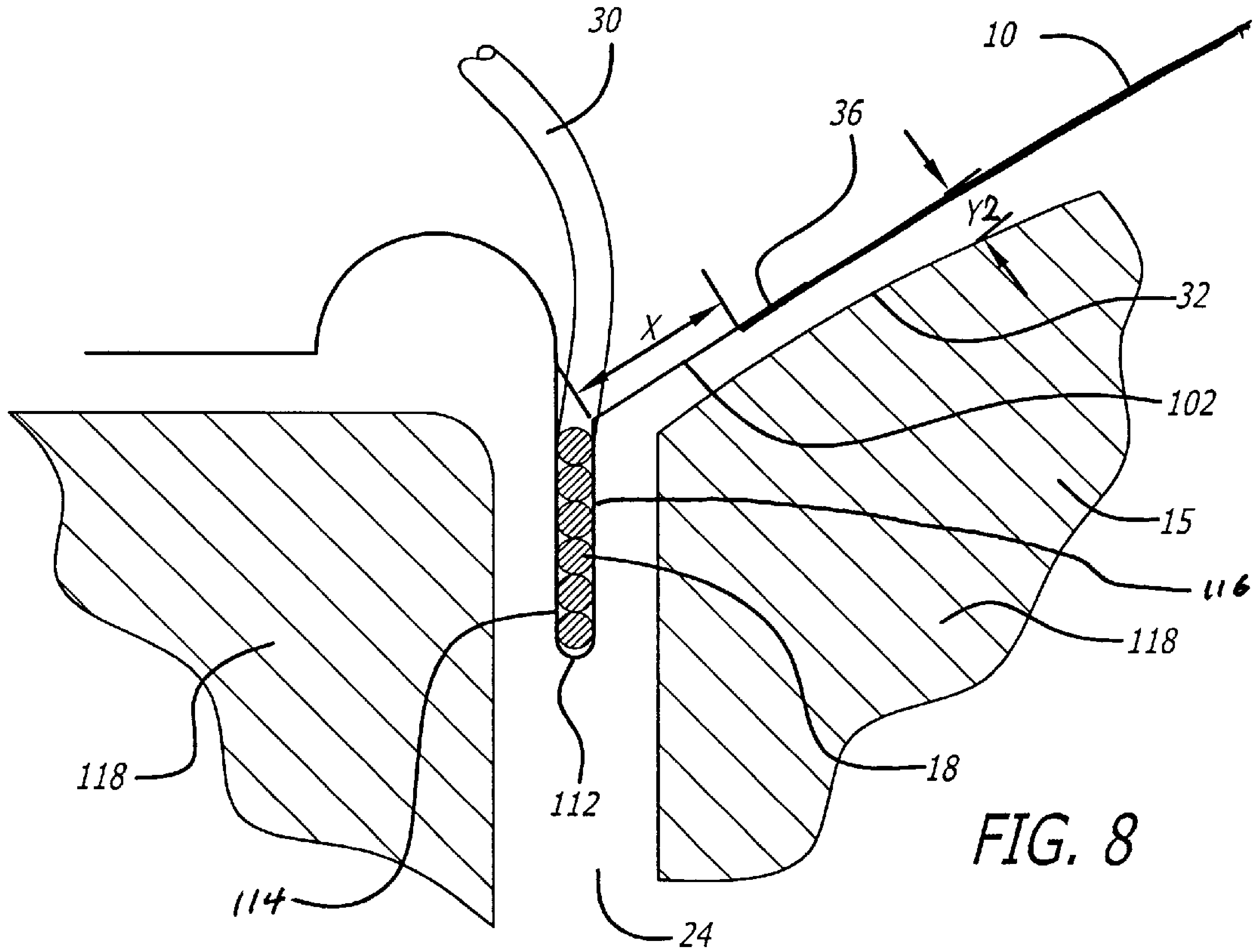

30
10
36
Y2
32
X
102
15
116
118
118
112
18
114
24

FIG. 8

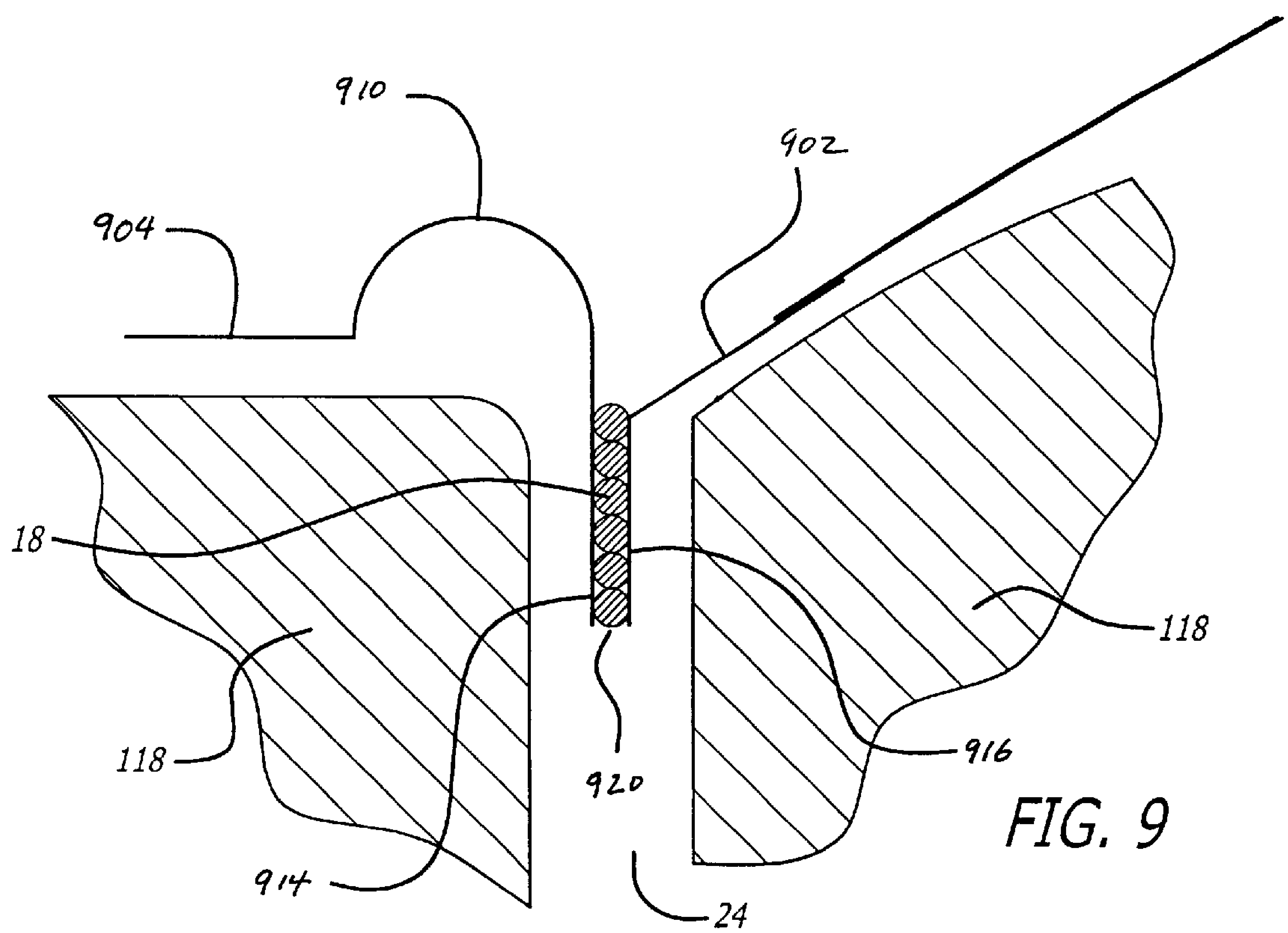

910
902
904
18
118
118
920
916
914
24

FIG. 9

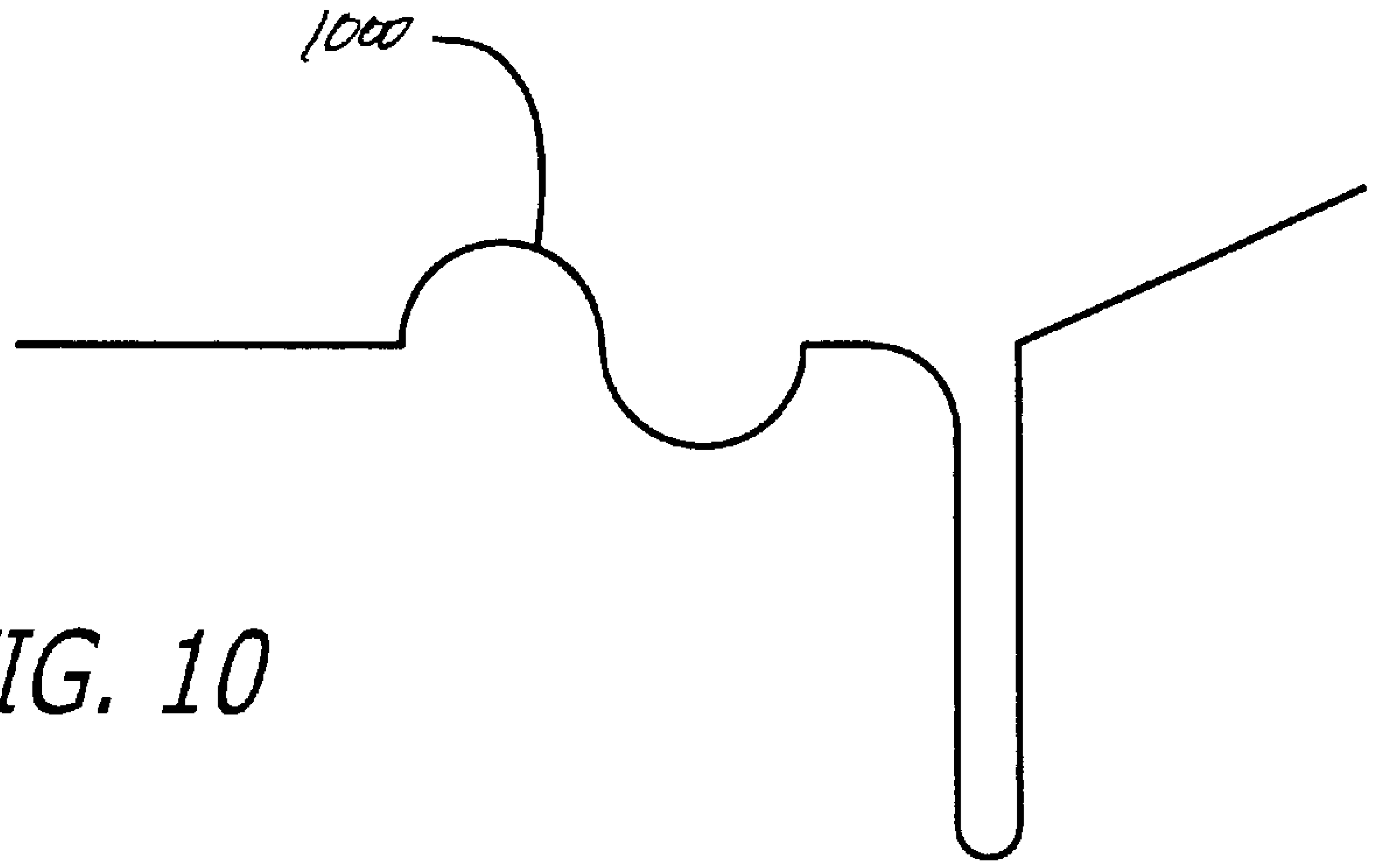


FIG. 10

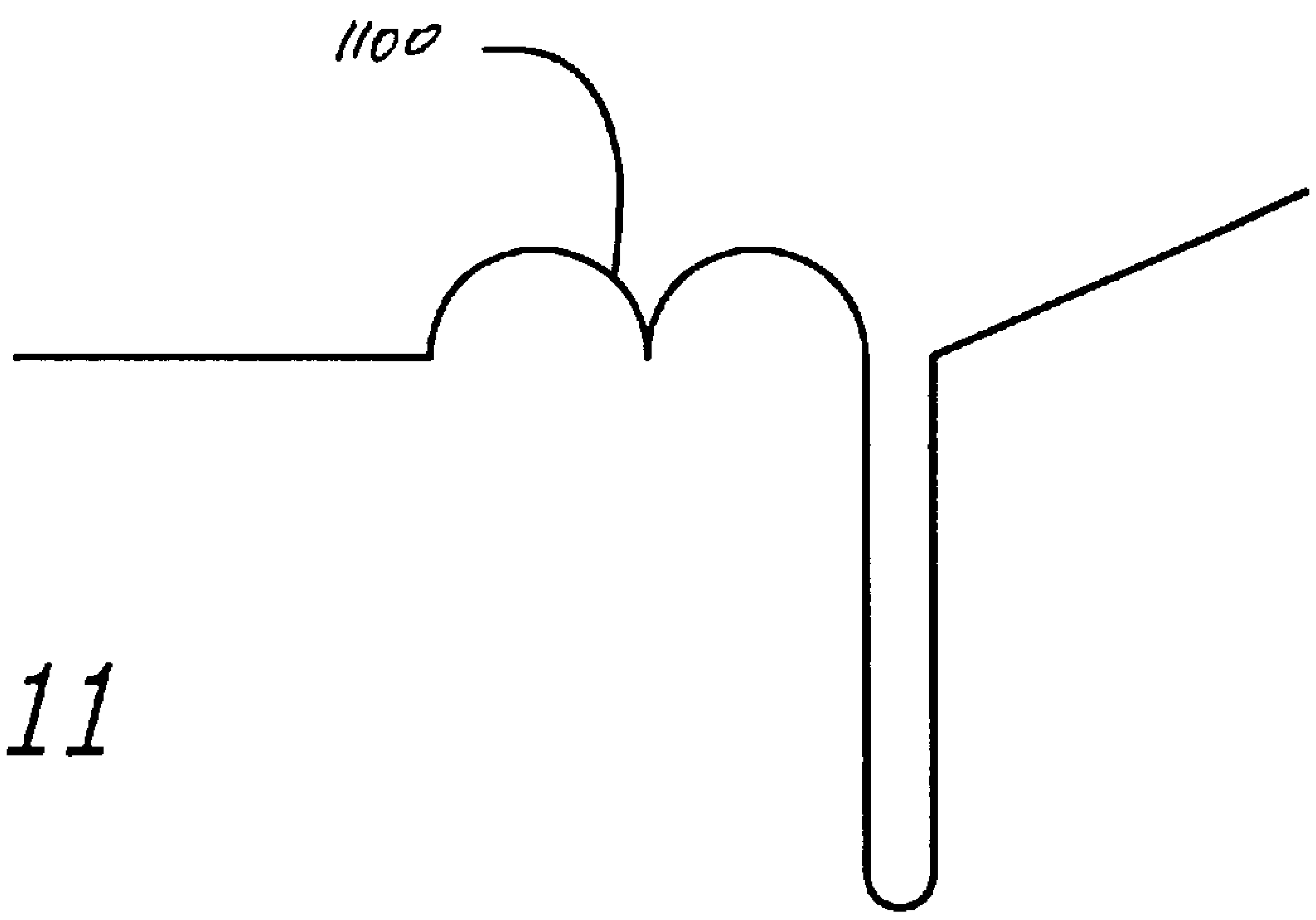


FIG. 11

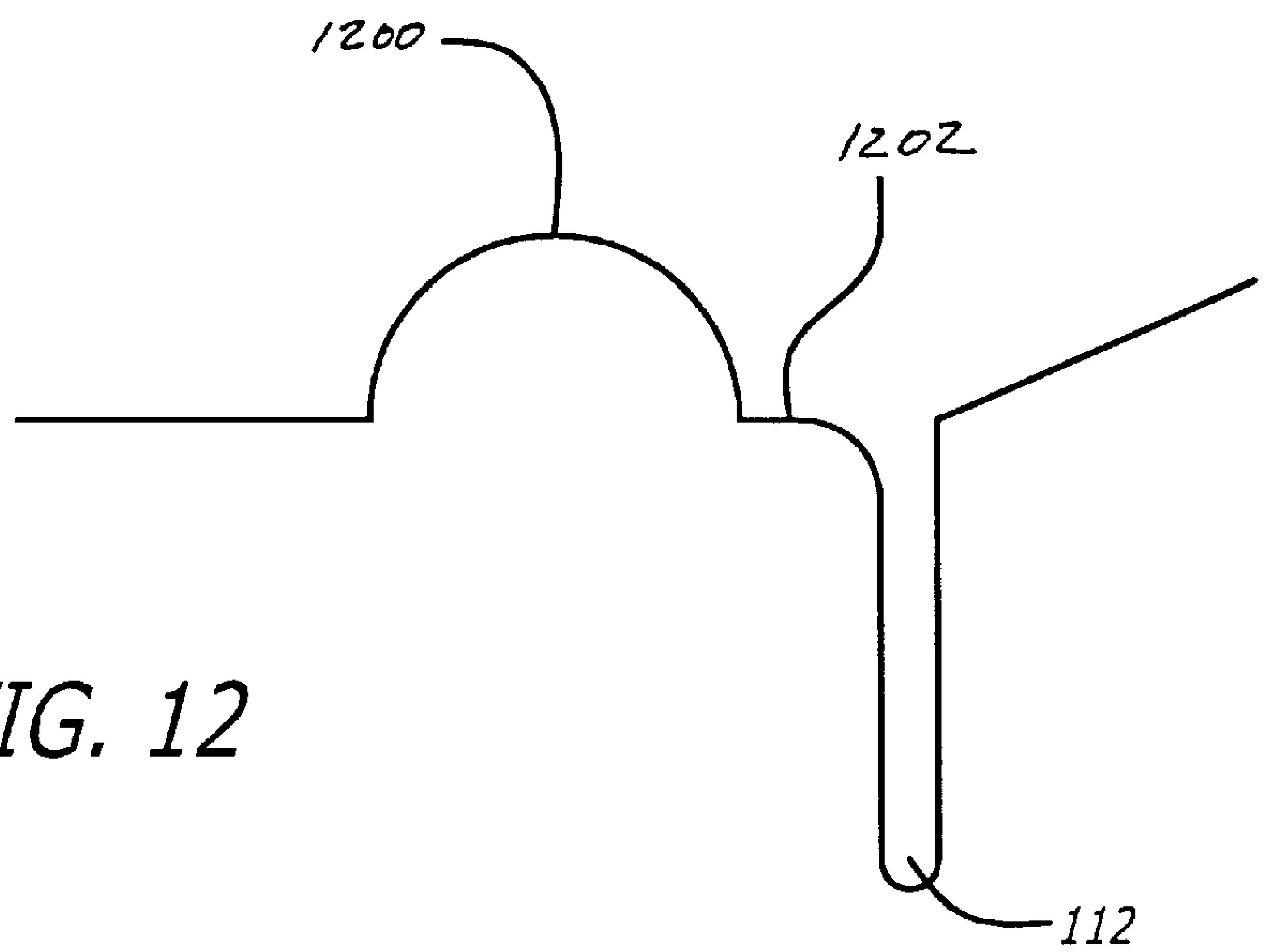


FIG. 12

LOUDSPEAKER COIL SUSPENSION SYSTEM

CROSS-REFERENCES TO RELATED APPLICATION

This application is a non-provisional application claiming priority to U.S. provisional application, Ser. No. 60/221,693 filed Jul. 31, 2000.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a loudspeaker coil suspension and dome system that acts to protect the coil from electrical shorting.

2. Related Art

A loudspeaker is a device for converting variations of electric energy into corresponding variations of acoustic energy. To convert the electrical energy into sound, a combination of a diaphragm and a compression driver is coupled to the throat of a horn. The compression driver typically includes a phasing plug made of ferromagnetic material having a plurality of bores between the rear side and the front side of the phasing plug.

Generally, the coil is wrapped around the exterior side of a cylindrically shaped former. The combination of the former and coil are then disposed within an annular magnetic gap enabling free vibration in a direction along the longitudinal axis of the former. The vibration causes a corresponding vibration of the diaphragm generating sound. The suspension needs to flexible in order to accommodate the excursion of the cone or diaphragm. At the same time, the suspension needs to keep the cone or diaphragm from tipping or becoming "de-centered."

To suspend the diaphragm adjacent to the rear side of the compression driver, the outer perimeter of the diaphragm is coupled to a suspension, which in turn is attached to a mounting plate. With the configurations that have been used in the past, the outer surface of the voice coil is substantially exposed and not insulated.

To generate sound, a static magnetic field, usually produced by a permanent magnet, is applied so that an alternating signal current flowing through the voice coil causes it to vibrate along its cylindrical axis. This in turn causes the diaphragm to vibrate along the axis of the plurality of bores and generate sound waves corresponding to the signal current. The sound waves are directed through the bores toward the front side, which then radiates the sound waves into the air through the horn.

Despite best manufacturing efforts, speakers may fail due to excessive mechanical and thermal stresses. For example, suspensions can fail due to environmental factors such as exposure to heat, UV rays or humidity. Adhesives attaching the suspension to the diaphragm can also fail if applied improperly or if excess mechanical stress is applied to the jointing area. Likewise, adhesives attaching the former to the diaphragm can fail. This happens because applying adhesive between the suspension and the diaphragm, and between the former and the diaphragm, can be a delicate process and possibly misapplied. Another way the loudspeaker might fail is due to over heating of the voice coil. If the voice coil experiences excessive heat expansion, it may come into contact with the sidewalls of the magnetic gap. If this condition occurs and the voice coil is not insulated, the resulting contact between the voice coil and the sidewalls can cause an electrical short circuit and terminal failure will occur.

Another shortcoming of current compression driver devices is that additional acoustic energy may not be provided in high frequency applications. In high frequency applications, additional acoustic energy is desired from the compression driver, but with current designs such additional acoustic energy may not be provided. Therefore, there is a need for a compression driver that can generate additional acoustic energy at high frequency application, a coil and suspension assembly system whose manufacturing process is simplified and a system for protecting the voice coil from experiencing electrical short circuits.

SUMMARY

This invention provides an assembly system for a voice coil, suspension, and diaphragm. In one embodiment of the invention, a continuous layer of high temperature resistant polymer is shaped to form a suspension, a pocket adapted to receive the voice coil and a flange adapted to couple to the diaphragm. A continuous layer of polymer may be shaped to perform several functions, such as the suspension, the former, and an attachment to the diaphragm. The coil may be inserted inside the pocket to protect the voice coil from electrical shorting as the voice coil expands or shrinks. The assembly system may also allow for the manufacture of different products via simply changing the diaphragm material. The diaphragm can then be optimized for different uses by changing materials. This may provide manufacturing flexibility by allowing various products to be assembled by the same tooling.

This invention may also allow utilization of an inner flange area of a suspension to act as a spring allowing the generation of additional acoustic energy from the compression driver. The inner flange area may be tuned to vibrate at a predetermined high frequency thus adding additional acoustic energy to the diaphragm motion. In certain applications where more acoustic energy is desired, the inner flange area may be tuned to provide that extra acoustic energy.

To further increase the high frequency energy generated by the compression driver, the diaphragm may be coupled to the bottom side of the inner flange area. Such an arrangement places the diaphragm closer to the phasing plug minimizing the space or cavity between the two items. With a smaller cavity, the resonance in the cavity increases, resulting in an increase in the high frequency energy generated by the compression driver.

Other systems, methods, features and advantages of the invention will be or will become apparent to one with skill in the art upon examination of the following figures and detailed description. It is intended that all such additional systems, methods, features and advantages be included within this description, be within the scope of the invention, and be protected by the accompanying claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention can be better understood with reference to the following figures. The components in the figures are not necessarily to scale, emphasis instead being placed upon illustrating the principles of the invention. Moreover, in the figures, like reference numerals designate corresponding parts throughout the different views.

FIG. **1** is a cross-sectional view of a compression driver.

FIG. **2** is a top view of a unitary suspension pocket attachment.

FIG. **3** is a cross-sectional view along line **3**—**3** in FIG. **2**.

FIG. **4** is a close-up cross-sectional view along an encircled area **4** in FIG. **3** illustrating a pocket disposed within a voice coil gap.

FIG. **5** is a cross-sectional view of a unitary suspension pocket attachment of the embodiment illustrated in FIG. **4**.

FIG. **6** is a cross-sectional view of a unitary diaphragm pocket suspension.

FIG. **7** is a close-up cross-sectional view of an inner flange being coupled to a diaphragm.

FIG. **8** is a close-up cross-sectional view of an alternative embodiment illustrating an inner flange being coupled to a diaphragm.

FIG. **9** is a cross-sectional view of an alternative embodiment of a pocket insulating a voice coil.

FIG. **10** is a cross-sectional view of an alternative half-roll.

FIG. **11** is a cross-sectional view of an alternative embodiment of a half-roll.

FIG. **12** is a cross sectional view of an alternative embodiment of a unitary suspension pocket attachment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. **1** illustrates a cross sectional view of a compression driver **12** coupled to the throat **14** of a horn **16**. To convert the electrical energy into sound, a combination of a diaphragm **10** and a phasing plug **15** is coupled to the throat **14** of a horn **16**. The phasing plug **15** may be made of ferromagnetic material that has a plurality of bores **30**A between the rear side **32** and the front side **34**. The coil **18** is insulated and disposed within an annular magnetic gap **24** to vibrate freely in a direction along the longitudinal direction. To suspend the diaphragm **10** adjacent to the rear side **32** of the phasing plug **15**, the outer perimeter of the diaphragm **10** is coupled to a suspension **20**, which in turn is attached to a mounting plate **22**.

FIGS. **2–6** illustrate a unitary suspension pocket attachment ("USPA") **100**. The USPA **100** performs several functions, including: (1) acting as a suspension or compliance to accommodate the excursion of the diaphragm; (2) acting as a voice coil former; (3) attachment to a diaphragm or dome; and (4) voice coil overdrive protection.

FIG. **2** illustrates a top view of the USPA **100** having an inner flange areas **102** substantially forming a circular opening adapted to couple to a diaphragm **200**. The USPA **100** also has outermost flange areas **106** adapted to couple to a mounting plate. And the intermediate outer flange areas **104** are free to move along the longitudinal axis and move with the vibration of the diaphragm **200**. That is, in this embodiment, the USPA **100** has an outer perimeter outline **108** that is substantially square with its corners rounded off. Disposed within the USPA **100** is a voice coil having two lead wires **30** extending from the USPA **100**. Other outer perimeter outlines may be configured by one skilled in the art.

FIG. **3** illustrates by way of example a cross-sectional view along a line **3—3** in FIG. **2**. In particular, FIG. **3** shows the diaphragm **200** having a dome shape coupled to the USPA **100**. FIG. **4** illustrates, an enlarged view of the encircled area **4** in FIG. **3**. In this embodiment, the voice coil **18** is disposed within the pocket **112**, which insulates the voice coil **18** from the sidewalls **118** forming the voice coil gap **24**. That is, the pocket **112** allows the voice coil **18** to expand or contract without shorting out the voice coil thereby preventing a terminal failure.

FIG. **5** illustrates the USPA **100** comprised of several portions, including the intermediate outer flange area **104**, a half-roll **110**, a pocket **112**, and the inner flange area **102**, all continuous one piece. In particular, the pocket **112** may form a deep U shape, defined by an outer wall **114** and an inner wall **116**. In this embodiment, the intermediate outer flange area **104** is free to vibrate as the diaphragm vibrates along the longitudinal axis. In other cross-sectional views, the intermediate outer flange area **104** may be the outermost flange area **106** that is adapted to couple to the mounting plate **22** as illustrated in FIG. **1**.

From left to right in FIG. **5**, the intermediate outer flange area **104** transitions to form the half-roll portion **110**, which is shaped like a dome. The dome shape allows the half-roll **110** to act like a spring. Moreover, the half-roll portion **110** needs to be flexible in order to accommodate the excursion of the cone or diaphragm. At the same time, it is adapted to keep the cone or diaphragm from tipping or becoming "de-centered." The half-roll portion **110** is not limited to the dome shape described above, and may take on different shape as known to one skilled in the art.

The half-roll **110** then transitions to form the pocket **112**, which may be shaped like a deep U, the pocket **112** then transitions to form the inner flange area **102**. The pocket **112** may be adapted to hold a voice coil within the pocket **112** between the outer wall **114** and the inner wall **116**. This positioning also insulates the side walls **118** that form the magnetic gap **24**. This allows the voice coil **18** to expand or contract without shorting out because the pocket's side walls **114, 116** protect the voice coil from electrically contacting the steel walls **118** of the compression driver **12**. With the USPA **100**, there is no need to manufacture a separate former, which reduces the cost of manufacturing the loudspeaker. The inner flange area **102** extends from the USPA **100** and provides more secure attachment because there is more surface area between the flange **102** and the diaphragm **10** in which to apply the adhesive more evenly.

The curvature of the diaphragm **10** may vary depending on the application. One of the advantages of the invention is that diaphragm (or sometimes referred to as a dome) of different curvature can be placed in the USPA **100**. For instance, the steeper in curvature the dome is or smaller the radius of the dome, stiffer the dome becomes, i.e., higher in the frequency resonance modal behavior. On the other hand, as the curvature flattens or as the radius of the dome gets greater, there may be more resonance in the response.

A variety of methods known to one skilled in the art may be used to bond the USPA **100** to the diaphragm **10**. For example, adhesives such as epoxy may be used to bond the USPA **100** to the diaphragm **10**. With regard to the USPA **100**, a variety of materials known to one skilled in the art or developed in the future may be used. For example, a variety of flexible plastic materials may be used, such as a polyimide such as KAPTON® polyimide. Other metal material such as aluminum may be used as well. The USPA **100** as configured in FIG. **5**, may be manufactured by Mogami Denki Corporation, 954-1 Manurogawa, Mogami-Gun, Yamagata, 999-53 Japan, using plastics such as KAPTON® polyimide. Furthermore, a diaphragm made of a variety of materials may be used in conjunction with the USPA **100** to create different sound. For example, a diaphragm made of plastic, carbon fiber, titanium, beryllium, and aluminum, may be used with the USPA **100** depending on the application. U.S. Pat. No. 5,883,967 entitled "Slotted Diaphragm Loudspeaker" issued to William Neal House, assigned to Harman International Industries, discussed a variety of other methods of constructing a diaphragm, which is hereby incorporated by reference to this application.

FIG. 6 is, a cross-sectional view of another embodiment of the invention, having a unitary diaphragm pocket suspension ("UDPS") **600**. In this embodiment, the diaphragm **602**, the pocket **612**, the half-roll **610**, and the outer flange **604** may be made of one piece. With this embodiment, the inner flange may extend to form the diaphragm **602**. This configuration minimizes the manufacturing costs because the flange no longer needs to be bonded to the diaphragm **602**. When adhesive is used to couple the flange to the diaphragm, there may be variations in applications of the adhesive. Such variations can cause differing stiffness, mass, dampening characteristics, be difficult to control, and may result in variations in the frequency response of the loudspeakers. However, with this embodiment, there is no need for adhesive to bond the flange to the diaphragm **602**. With regard to material, a variety of materials may be used, that is, the UDPS **200** may be made of plastic such as KAPTON® polyimide and aluminum.

FIG. **7** illustrates yet another aspect of the invention, utilizing an inner flange area **102** to act as a spring to generate additional acoustic energy from the compression driver. That is, the diaphragm **10** may be coupled to the inner flange **102** at a predetermined distance X from the inner wall **116**. As such, the diaphragm **10** and the inner flange **102** are coupled to each other between the contact area **36**. By varying the distance X in which the diaphragm is coupled to the inner flange **102**, the inner flange **102** can be tuned to act like a spring so that it can vibrate at a certain high frequency resonance. This way, the inner flange **102** can be tuned to vibrate at a high frequency resonance to add additional acoustic energy to the compression driver. In other words, as the inner flange resonates at certain high frequencies, the vibration of the flange **102** adds to the back and forth stroke motion of the voice coil **18** thereby adding energy to the vibration of the diaphragm **10**. Thus, in certain applications where more power is desired from the compression driver as in a rock and roll concert, the above described embodiment may be used to add additional acoustic energy. Note that as the predetermined distance X gets shorter, the inner flange **102** acts like a stiffer spring so that the inner flange **102** will resonate at a higher frequency.

FIG. **8** illustrates still another alternative embodiment of the invention where the diaphragm **10** is coupled to the under side of the inner flange **102** at a predetermined distance X away from the inner wall **116**. With the diaphragm **10** coupled to the under side of the inner flange **102**, the diaphragm **10** is closer to the rear side **32** of the phasing plug **15** so that the gap **Y2** between the diaphragm **10** and the rear side **32** here is less than the gap Y1 in the embodiment illustrated in FIG. **7** with the diaphragm on the top side of the inner flange **102**. There are several advantages to this embodiment. First, the diaphragm is further away from the lead wire **30** so that they are further isolated from one another. Accordingly, there is less risk of the lead wire **30** and the diaphragm **32** coming into contact and causing a short. Secondly, in this embodiment the diaphragm **10** is closer to the rear side **32** of the phasing plug **15** to generate additional high frequency energy from the compression driver. In other words, because there is less cavity space between the diaphragm **10** and the rear side **32**, the cavity resonates at a higher frequency to provide additional energy through the compressor driver. However, the distance **Y2** should be wide enough so that the diaphragm **10** does not come into contact with the rear side **32** when operating at low frequencies, which may cause a short under such circumstances.

FIG. **9** illustrates still another embodiment of the invention where the outer flange area **904**, half-roll portion **910**, and the outer wall **914** are made of one piece and the inner wall **916** and the inner flange **902** are made of another piece. Disposed between the outer wall **914** and the inner wall **916** is a voice coil **18** which is insulated by the two walls but exposed on the bottom side **920**. To enclose the bottom side **920**, a bottom cover may be coupled to the bottom side to further protect the voice coil **18**. One of the advantages with this embodiment is that the two side rolls **914** and **916** protect the voice coil **18** along its side where the damage is most likely to occur.

Although this invention has been described in terms of the embodiments discussed above, numerous modifications and/or additions to the above-described embodiments would be readily apparent to one skilled in the art. For example, as disclosed in FIGS. **10** and **11**, the shape of the half-roll may vary, like half-roll **1000** shaped like a sine wave, and a half-roll **1100** shaped like a "m." Still further, as shown by way of example in FIG. **12**, an extension **1202** may be formed between the suspension **1200** and the pocket **112**.

While various embodiments of the application have been described, it will be apparent to those of ordinary skill in the art that many more embodiments and implementations are possible within the scope of this invention. Accordingly, the invention is not to be restricted except in light of the attached claims and their equivalents.

What is claimed is:

1. A suspension member adapted to couple to a diaphragm and vibrate along a longitudinal direction a magnetic gap, the suspension member comprising:

a pocket adapted to vibrate within the magnetic gap, the pocket having an outer wall and an inner wall, where the inner wall extends to form an inner flange outside of the magnetic gap that is adapted to couple to a top side of the diaphragm, and the outer wall extends to form a half-roll that further extends to form an outer flange that is adapted to couple to a mounting plate of a compression driver.

2. The suspension member according to claim **1**, where the pocket has a deep U shape.

3. The suspension member according to claim **1**, where the outer wall, half-roll, pocket, and inner wall are unitary formed from a plastic material.

4. The suspension member according to claim **1**, where the plastic material is KAPTON polyimide.

5. The suspension member according to claim **1**, further including a voice coil in the pocket between the inner and outer walls.

6. The suspension member according to claim **1**, where the diaphragm is coupled to the inner wall at a predetermined distance away from the inner wall, where the inner flange along the predetermined distance functions as a spring to vibrate at a predetermined high frequency resonance.

7. The suspension member according to claim **1**, where the inner wall and the outer wall are separate from each other.

8. A system for adding acoustic energy to a compression driver having a magnetic gap, the system comprising:

a suspension having a pocket adapted to vibrate within the magnetic gap, the pocket having an inner wall and outer wall, an inner flange extending from the inner wall a outside of the magnetic gap, where the inner flange is adapted to couple to a diaphragm at a predetermined distance from the inner wall so that the inner flange vibrates substantially at a predetermined frequency resonance, where the diaphragm is coupled to a topside of the inner flange outside of the magnetic gap, and where the outer wall extends outside of the magnetic gap to form an outer flange that is adapted to couple to a mounting plate.

9. The system according to claim **8**, where the inner wall is disposed into the magnetic gap in the compression driver.

10. The system according to claim **8**, where the diaphragm is coupled to the inner flange closer to the inner wall to tune the inner flange to vibrate at a higher frequency resonance.

11. The system according to claim **8**, where the inner wall extends to form an outer wall to form the pocket, where the inner wall and the outer wall are formed from a unitary plastic material.

12. The system according to claim **11**, including a voice coil into the pocket, where the voice coil oscillates within the magnetic gap based on signal current flowing through the voice coil.

13. A system for vibrating a diaphragm along a longitudinal direction of a magnetic gap, the system comprising:

a diaphragm having a top side; and

a suspension member having a unitary pocket adapted to vibrate within he magnetic gap, the pocket having an inner wall and outer wall, where the inner wall extends outside of the magnetic gap to form an inner flange that is couple to the top side of the diaphragm, and where the outer wall extends outside of the magnetic gap to form an outer flange that is adapted to couple to a mounting plate of a compression driver.

14. The system according to claim **13**, where the inner flange is coupled to the diaphragm at a predetermined distance to vibrate the diaphragm at a predetermined frequency resonance.

15. The system according to claim **13**, where the pocket is formed from KAPTON polyimide.

16. A system for vibrating a diaphragm along a longitudinal direction of a magnetic gap, the system comprising:

a diaphragm having a top side; and

a suspension member having a pocket adapted to vibrate within the magnetic gap, the pocket having an inner wall and outer wall, where the inner wall extends outside of the magnetic gap to form an inner flange that is coupled to the top side of the diaphragm at a predetermined distance to vibrate the diaphragm a a predetermined frequency resonant, and where the outer wall extends outside of the magnetic gap to form an outer flange that is adapted to couple to a mounting plate.

17. The system according to claim **16**, where the pocket is a unitary piece.

18. The system according to claim **16**, where the pocket is formed from KAPTON polyimide.

19. A system for adding acoustic energy to a compression driver having a magnetic gap, the system comprising:

a suspension having a pocket adapted to vibrate within the magnetic gap, the pocket having an inner wall and an outer wall, an inner flange extending from the inner wall and outside of the magnetic gap, where the inner flange is adapted to couple to a diaphragm a predetermined distance from the inner wall so that the inner flange vibrates substantially a predetermined frequency resonance, where the diaphragm is coupled to a bottom side of the inner flange so that the diaphragm is closer to a phasing plugs and where the outer wall extends of the magnetic gap to form an outer flange that is adapted to couple to a mounting plate.

* * * * *